OBSERVATIONS

ON THE

EFFECTS PRODUCED BY THE 6-MM. RIFLE AND PROJECTILE

6.

AN EXPERIMENTAL STUDY

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Reprinted from
The Journal of the Boston Society of Medical Sciences
January, 1899

BOSTON
MASSACHUSETTS
U.S.A

OBSERVATIONS ON THE EFFECTS PRODUCED BY THE 6-MM. RIFLE AND PROJECTILE.

AN EXPERIMENTAL STUDY.

By Henry G. Beyer.

The experiments which will be found described in the pages that follow were made in the harbor of Port Royal, S.C., where the United States Steamship "Amphitrite" was engaged in the training of gun captains, during the four months immediately preceding the outbreak of hostilities between this country and Spain.

The navy having recently been equipped with a new small-arm of special description, with a projectile of certain definite dimensions and a composition marking it out as differing from other projectiles, it had become necessary to determine its effects upon animal tissues and organs by the usual experiments made with this end in view.

The United States Navy Rifle, M. 1895, is known as the "Lee Straight Pull Rifle,"[1] and is a rapid-fire and repeating arm rather than a magazine gun. It may be used as a single loader, if the magazine be not charged, but in general it will be used as a repeater, five cartridges in a clip being entered in the magazine, and the gun not being reloaded until this charge is exhausted. In case loose ammunition is furnished, the magazine may be charged with single cartridges, any number from one to five being entered.

The original bullet was made of hardened lead (95% lead and 5% antimony), with a jacket of a material known as cupro-nickeled steel. It was steel plated with an alloy of copper and nickel. The weight of the bullet was 135 grains. In March, 1897, a change was made in the bullet, bringing the weight down to 112 grains, substituting a copper jacket, tinned, in place of the steel jacket, covered with an alloy of

[1] Alger and Twining.

copper and nickel, thus raising the velocity from 2,460 to 2,560 feet per second, thereby, however, also increasing its liability to deformity.

All authorities are agreed that one of the most important qualities tending to increase the penetrative power of a modern small-arm projectile is the hardness of its mantle or jacket. Whenever we depart from a hard-steel jacket and substitute for it the softer copper jacket, for example, the penetrative effect of our projectile must be proportionately decreased, while its explosive effect must be correspondingly increased.

On the other hand, according to Kocher, all those qualities in a projectile which are calculated to increase its penetrative power tend also to decrease its explosive effects; [1] and, according to the experiments made by Bruns, the hydraulic pressure, although increased, as a rule, with increasing velocities, has not increased with the velocities in the same proportions, on account of the reduction in the calibre of the projectiles. This is held by Kocher to be true for the explosive effect in general.

Shots fired at Inanimate Material.

1. Jan. 6, 1898. Lead plate (see fig. 5, pl. I. and II.), 3 cm. thick, 8 cm. on a side, weight 2.25 kilos, suspended by rope-yarn from the upper cross-piece of a wooden frame, at a distance of 5 feet from the muzzle of the gun; white sheet of paper hung in front and rear of the plate; velocity of bullet 2,560 feet p. s.; entrance opening 24 mm. in diam., exit 36 mm. in diam.; channel funnel-shaped or conical. Front crown 6 mm. high, rear crown from 6 to 12 mm. Paper in front and rear sprinkled over with lead-colored spots, and perforated with numerous small and large very irregular holes. Small strips from the copper jacket may be seen lining the inside of the channel in the plate; some larger strips of copper, also, found in the oakum bag used for catching

[1] Nach unsern schon 1880 publicirten Nachweisen verringern alle Momente, welche, ceteris paribus, die Durchschlagskraft eines Geschosses erhöhen, dessen Sprengkraft (*loc. cit.*).

PLATE I.

Rubber — Rubber.

Lead — Lead.

Lead — Lead.

~~Entrances~~. (See Text.)

Exits.

PLATE II.

Rubber. Rubber.

Lead. Lead.

Lead. Lead.

~~Exits.~~ (See Text.)

Entrances.

the bullets, and placed directly in the rear of the lead plate. Small particles of lead were found on the floor. Loss in weight of plate was 16 grms.

2. s. d. Lead plate (see fig. 6, pl. I. and II.), same dimensions as preceding, disposed in same manner, and fired at with same velocity. Entrance 26 mm. in diam., exit 40 mm. wide; channel conical and showing small strips of copper jacket lining its walls. Paper in front and rear sprinkled over with grayish spots, and perforated with numerous small and large irregular holes. Bullet went completely to pieces, as in preceding experiment. Loss in weight of plate was 15 grms.

3. Feb. 11, 1898. Lead plate (see fig. 4, pl. I. and II.), same dimensions, and disposed in like manner as preceding ones; muzzle velocity of bullet 1,500 feet p. s., struck plate 5 feet from muzzle; diam. of entrance 20 mm., exit 12 mm. wide, or 8 mm. less than entrance, and bulging to the extent of 6 mm. above the surrounding surface; channel smooth and conical, but the wider portion of the cone is at the entrance. Parts of the copper jacket may be seen lining the channel. Loss in weight of plate was 13 grms.

4. March 5, 1898. Lead plate (see fig. 3, pl. I. and II.), of same dimensions as previous ones. Velocity of bullet 750 feet p. s. Entrance 10 mm. wide; there is no exit. Bullet may be seen lying imbedded in plate; its jacket is empty. The posterior surface of plate, at a point opposite the entrance of the bullet, shows some bulging.

5. Jan 6, 1898. Plate of fine soft rubber (see fig. 1, pl. I. and II.), 11 mm. thick, 10 cm. on a side, suspended by twine in a wooden frame, 5 feet from the muzzle of the gun, velocity of bullet 2,560 feet p. s. Entrance round, 2 mm. wide; surface of rubber adjacent to opening shows dark discoloration for a distance of 2 mm. Exit 9 mm. wide, irregularly round; channel funnel-shaped or conical and roughened; widest part of funnel is at exit.

6. s. d. Plate of fine soft rubber (see fig. 2, pl. I. and II.) in every respect same as preceding. The same plate shows an opening made by a bullet fired with a velocity of 1,500

feet. The entrance of this opening is 1 mm. wide, being, in fact, a mere point, with a distinct dark ring around it; exit is a mere pin-point, and smaller even than entrance. This is shown in the lower part of the photograph.

7. s. d. Tin can, 11 cm. high, 8.5 cm. wide (see fig. 8, pl. III. and IV.), empty, suspended by twine, accurately centred, fired at with a velocity of 2,560 feet p. s., 5 feet from the muzzle. Entrance 7 mm. wide, round, edges inverted. Exit 6 mm. wide, round, edges everted; tin can scarcely moved and the twine did not break.

8. Same sized tin can, filled with water (see fig. 9, pl. III. and IV.), suspended and fired at under the same conditions as in No. 7, was blown to pieces, water scattered in all directions; the pieces recovered were all bent out of shape.

9. s. d. Same sized tin can, filled with marbles (see fig. 13, pl. III. and IV.), fired at with velocity of 2,560 feet p. s., 5 feet from the muzzle. Entrance 7 mm. wide, and round. Exit is a large rent, a part of the wall of the can being carried away. The top flew out, the bottom is bulging and presents a triangular hole with everted edges. Impressions of the marbles are marked all around on the surface of the vessel. The marbles themselves show the effect of lateral compression, being flattened in certain places. The bullet went completely to pieces, and particles of lead and of the copper jacket were found in the oakum.

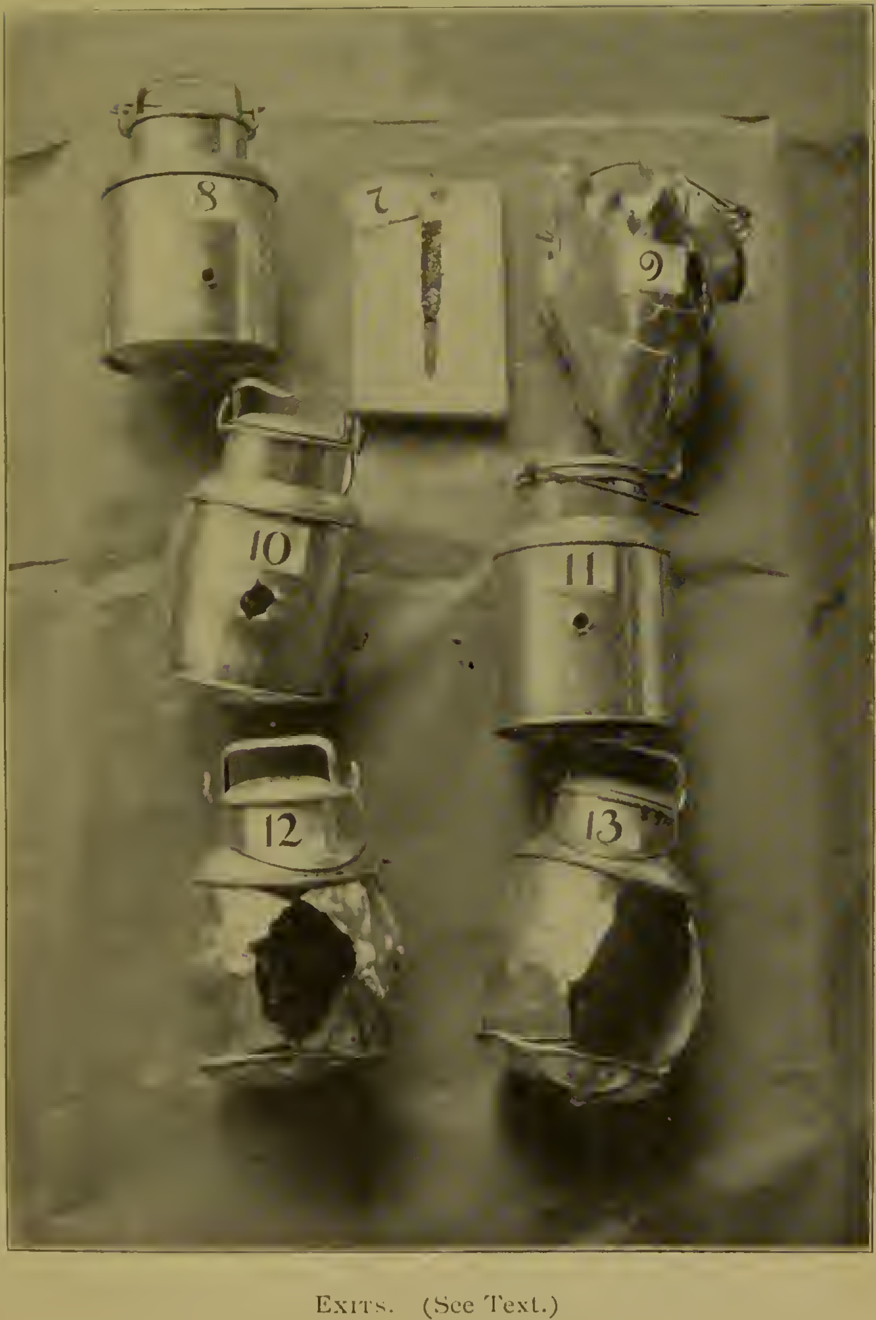
10. s. d. Same sized tin can, filled likewise with marbles (see fig. 12, pl. III. and IV.), and treated as preceding. The result was the same, with the exception that two rough irregular holes are to be seen a little to the right of the entrance, through which some marbles were pressed, making their way out of the vessel against the very direction whence the bullet came. The bullet was completely destroyed, small strips of the copper jacket and lead granules recovered among the marbles, which latter were partly ground into coarse powder and had partly fallen to the floor. Some of the marbles were also found in the oakum bag.

11. Feb. 11, 1898. Empty tin can (see fig. 11, pl. III. and IV.), fired at with a velocity of 1,500 feet p. s., 5 feet from

PLATE III.

ENTRANCES. (See Text.)

PLATE IV.



Exits. (See Text.)

the muzzle; scarcely moved and string unbroken; entrance 7 mm. wide and round; exit of same dimension and edges everted; bullet slightly compressed and flattened at point.

12. s. d. Same sized tin can, filled three-fourths full of water, suspended as before, fired at with a velocity of 1,500 feet, 5 feet from the muzzle (see fig. 10, pl. III. and IV.). Entrance transverse diam. 8 mm., vertical diam. 6 mm., prolonged into two fissures, the upper one of which is 6 mm. long, and the lower one 8 mm. long; edges slightly inverted. Exit irregularly quadrangular, 12 mm. at its widest part and 10 mm. at its narrowest part; edges everted and partly curled on themselves. The top flew off, completely bent on itself from without inward, so that it could not be replaced. The sides and bottom of the vessel are bulging outward. The twine only partly broken.

13. Jan. 18, 1898. Plate of finest chrome steel, 7 mm. in thickness, suspended and without any backing, fired at with full velocity, distance from muzzle 50 yards, twice in succession, producing two clean perforations, round and smooth, measuring 8 and 9 mm. in diam. respectively. The same plate with strong backing, fired at with the same velocity and at the same distance, showed deep impression, but no perforation. Distinct whitish star-shaped lines were seen around the impressions, due to melted particles of lead from bullets, which were not recovered.

14. Jan. 6, 1898. Square glass plate, 6 mm. thick, 15 cm. on a side, encased in a wooden frame, fired at 5 feet from the muzzle with a velocity of 2,560 feet. Large portion of the glass was blown out; the remainder shows circular and radiating cracks which are made very distinct, from their milky white appearance. The lines are filled with finely ground glass.

15. Feb. 11, 1898. Large tin can, completely filled with two kg. of dry plaster of paris. The vessel measured 16 cm. in diam. and 16 cm. from top to bottom, being cylindrical in shape and having a well-fitting cover. It was fired at through the centre, velocity 2,560 feet, 5 feet from the muzzle. Entrance round, 6 mm. in diam., but no exit was

found. The top cover was blown off and about 100 grms. of the powder were scattered over the floor. Immediate search made for the bullet resulted in finding it 2 cm. from rear wall, in a flattened condition, with very irregular outline, intimately mixed with the plaster and so hot that it could not be held with the fingers. The vessel showed no deformity whatever, and was not thrown out of the frame, remaining suspended.

16. A canvas bag, 90 cm. long and 25 cm. in diam., cylindrical in shape, completely filled and packed with ship's oakum, and weighing twenty-two and one-half pounds, was tied lengthwise on the top of a barrel, one end of the cylinder pointing inboard, the other end looking out to seaward. Both ends were covered with sheets of white paper and 5 shots were fired through this cylindrical bag parallel to its long axis, with full velocities and 5 feet from the muzzle. All 5 shots went through, a cloud of fine brown dust following each bullet as it went over the side of the ship. The bullets were seen to drop into the water at an estimated distance from the ship of 300 yards. Both the entrances and the exits were small and slit-like in the paper covers as well as in the canvas, indicating little or no deformity on the part of the bullets. The tracks made by the bullets within the oakum were lined with finely powdered oakum.

The same experiment was repeated two days later, but with oakum packed very tightly with a jack, with practically the same result, except that the bullets dropped into the water at a still greater distance from the ship's side than they did in the case of the bag not so tightly packed.

Nothing, certainly, can be better calculated to show the superiority of experimentation over mere speculation and scientific guessing than a comparison of the different effects produced by our projectile on the various inanimate substances which have been experimented on. A mere glance at the lead plates and the rubber plates will show the most unexpected differences in the effects produced by the same forces acting on them. Very remarkable is the degree of penetration shown in the several substances used. In plaster of paris, for instance, our projectile penetrates to the extent of only 14 cm., and is found to have become flattened like a pancake; while in firmly packed oakum its course is not checked at all, but the bullet passes through the entire length of the bag, a distance of 90 cm., then goes 300 yards further before its force becomes exhausted, and comes out without being deformed.

Figure 12, on plate III. and IV., represents a tin can that was originally filled with marbles. This tin can shows that a very high degree of pressure must have been exerted from some point in its centre in all conceivable directions and at the moment the bullet entered it. This vessel exhibits and illustrates what, according to Kocher, is the very highest degree of explosive effect. We see impressions produced by the marbles in the tin not only all around the sides of the vessel, but we notice also two irregular holes in close proximity to the point through which the bullet entered, and through which two holes several marbles cut their way through the tin against the very direction whence the bullet came.

In the lead plate, represented by figure 4, plates I. and II., in which the entrance is larger than the exit, the explosive effect was practically exhausted during its passage through it, while in figure 3, shown in the same plates and in which only an entrance is seen, with some bulging where the exit ought to be, the power of the bullet was exhausted before penetration could be completed.

The fact that the decreased penetrative power and the increased explosive effect exhibited by our projectile may be attributed to the softness of its mantle or jacket is also proven by some experiments by Kocher. Kocher experimented with two projectiles, of which the one had a calibre of 5.8 mm. and a velocity of 810 m.; the other a calibre of 7.5 mm. and a velocity of 610 m. The former, in spite of its much greater velocity, produced less explosive effect than the atter. Both bullets were provided with a hard steel jacket.

The very striking similarity that has been found to exist between the effects produced by a small-calibre bullet in the human skin and the lungs on the one hand, and an elastic rubber plate on the other, must be apparent to every one. It is, consequently, much more easy to understand that the ordinarily small size of the injuries in these structures is due chiefly to the fact that they contain an abundance of elastic tissue. Moreover, the fact that organs which contain within their meshes a certain fixed quantity of moisture, more or less large, experience injuries that become more serious the greater *cæteris paribus*, this quantity of moisture is, could only be satisfactorily explained on the principles underlying hydraulic and hydrostatic pressures. The further fact that the injuries in bones, especially the harder cortical portions in the diaphyses, are out of all proportion so much more serious than those produced by the same projectiles and moving with identical velocities, on the softer tissues, has become more intelligible by experiments on the more simple substances, such as glass plates, glass tubes, etc.

The most elementary and simple substances had to be interrogated in order to satisfactorily explain the nature of an injury produced in a complex structure.

Of scarcely less importance in this regard has been the study of the physical and chemical composition of the projectile itself. Two bullets, moving with the same velocities, have been found to produce widely differing effects, according to their composition. The tendency of progress in this respect has been marked by a steady, unfaltering advance toward increasing the hardness of the bullet and its mantle. In this direction some improvement seems, however, still to be desirable, since there is scarcely a projectile known which, moving with the enormous velocities at present obtainable, does not suffer deformity on striking hard substances, even at considerable distances from the muzzles of the guns. At present, velocity seems to be far ahead of the durability of the projectile, and, consequently, any change from a hard mantle of a projectile to a softer one must be regarded as a step backward rather than forward, especially so since the gain in velocity through the reduction in weight which is thereby made is practically superfluous.

In view of the facts at present on hand, and considering the very great distance from the muzzle of a modern small-arm at which a man may still be placed *hors de combat*, we have reached a limit beyond which, according to Kocher, it would hardly seem to have any sense to go.

When we now examine a little more closely the results obtained with our rifle on some of the inanimate material enumerated above, the first thing which will attract our attention is the difference in the injuries produced by the same projectiles, but moving with different velocities. In the first four shots, through lead plates, we see these differences well marked. The projectiles being the same in all four cases, the differences produced can only be due to the differences in the velocities with which they struck the plates. In the first three shots the bullets went completely to pieces; in the fourth a part of the jacket alone remained entire, losing its lead.

The heat produced on impact was evidently great enough to melt the lead of the plate as well as that in the bullet, as is shown by the large number of holes in the paper hung up in front and rear of the plate, and by its grayish discoloration. Since Kocher has shown that particles of lead only separate from a projectile, or other material made of lead, whenever the lead becomes heated up to the melting-point, the above-described appearances on the paper, as well as the fact that small particles of lead were picked up from the floor of the room, must be accepted as sufficient proof of the fact that the lead did melt when the bullets struck the plates. In addition to this we have the further fact of a loss in weight of the plate, amounting to from 13 to 16 grammes in the different cases.

That hydrostatic pressure is either increased or decreased in direct proportions to increasing or decreasing velocities is well exemplified in our experiments on the tin cans filled with water. With full velocities the can is simply torn to pieces, while with lower velocities the can not only remains entire, but the exit is not a rent, but simply a quadrangular opening. In both cases, however, the bullets showed considerable deformity. The full-velocity bullet had lost all its lead, and the jacket was torn and bent upon itself. The lower-velocity bullet had also lost its lead, but the jacket showed merely a turning down of its anterior end, the margins of the sleeve being serrated.

The experiments on tin cans filled with marbles would, to my mind at least, illustrate beautifully Kocher's dry pressure theory and its analogy to hydrostatic pressure, as produced in wet or moist substances. In both these instances the effect of lateral pressure is well shown, and there seems to be little or no essential difference in the cans whether they were filled with water or with marbles.

In all the experiments so far made our bullets suffered deformity, from a mere flattening of the anterior end to their complete destruction.

Shots fired through Animal Tissues and Organs.

A. BRAINS AND VISCERA.

Most of the material used in this series of shots was furnished me by butchers who did their own killing, and was obtained in a perfectly fresh, often still warm condition. The dissection and examination of the effects produced by the shots were done on the spot, and the results recorded.

1. Feb. 1, 1898. A small ox was killed by a shot through its head. Bullet velocity was 2,560 feet, distance 10 feet. Bullet entered skull in front, a little above line connecting the upper margins of the two orbits. The animal dropped immediately into the suspension apparatus previously provided for it and made fast above. Entrance opening in skin was 7 mm. in diam., slightly bevelled. Underneath the skin is a loose piece of bone, lozenge shaped; its centre presents a small hole equal in size to that in the skin, but widening towards the inner surface, where it measures 12 mm. This piece of bone is 5 cm. long and 3 cm. broad; removed, it shows the brain to be a shapeless mass, covered with coarse, bony detritus derived from the internal table of the skull.

In this mass of the brain, bony detritus, and blood were found pieces of lead and thin strips from the copper jacket. Several long transverse fissures in the skull were also noticed.

2. March 12, 1898. Calf, seven months old, was shot through the head; velocity of bullet was 1,484 feet, entering 5 feet from muzzle, animal standing with its left side toward the gun. The animal turned half a circle from left to right, then fell to the ground, but immediately rose again on its feet, having, apparently, retained complete voluntary control of all its limbs as well as of the muscles of its neck, trying to run away from its halter. A second shot through the neck and spinal cord a little below the skull felled and killed the animal instantly.

The first shot entered the skull cavity at a point 1 cm. behind and below the attached portion of the left ear. The entrance opening was 6 mm. in diam. The exit was found 1 cm. above the bony margin of the orbit and the outer angle of the right eye. Both eyes were prominent and protruding abnormally. The skin opening at exit did not exceed the diam. of the bullet, but the finger felt an opening in the bonyskull underneath, somewhat larger than that in the skin, with a fringe of fine, sharp bony spicules projecting from the margin toward the centre of the skin opening. This shot, then, passed through the calf's head in a direction from left to right, and from behind forward, the animal turning its head slightly to the right at the moment of firing. On removing the calvarium with the small bones attached a clean perforative opening in the skull was found, without any splintering. A few very fine short fissures extending through the dura mater were seen around the opening in the occipital portion of the skull The bullet passed on through upper portions of the cerebellum on the left side, going directly forward and to the right, passing through the occipital lobe of the cerebrum, through both ventricles above basal ganglia, coming out through middle frontal convolution of right half of the cerebrum, and leaving the skull cavity through a typical opening in the frontal bone. The track throughout the brain was but slightly larger than the diam. of the bullet, even and smooth, without laceration of any kind, and marked from one end to the other by a narrow line of bright red blood, which filled the channel without distending the same. The rest of the brain had preserved its consistency and form in a perfectly normal condition. Although the projectile was not recovered, it could have experienced but little deformity. Ossification in the young skull had not, of course, been completed at that age.

3. Jan. 8, 1898. The lungs from a pig, freshly killed, inflated and suspended, were fired at with full velocity, 20 feet from the muzzle. Bullet entered the centre of right middle lobe, making an opening of 15 mm. in diam., a smooth track of the same diam. throughout, and leading to an exit 20 mm. wide.

4. Jan. 22, 1898. Pig's lungs, freshly killed and inflated, were fired at with a velocity of 1,000 feet p. s., 5 feet from muzzle. Both entrance and exit smaller than diam. of bullet, so that it is difficult to find either after partial collapse of the lungs.

5. Jan. 22, 1898. Perfectly fresh cow's liver. Full-velocity bullet, at 5 feet from the muzzle, passed through centre of flat surface, and caused a rent 19 cm. long, 7 cm. wide, with edges ragged and torn and three fissures 1 cm. deep, and extending 4, 7, and 9 cm. respectively from the margin of the entrance opening. The exit was 20 cm. long, 9 cm. wide, its edges pulped and everted without fissures. The liver substance was scattered over white sheets of paper, hung up in front and rear.

6. March 5, 1898. Fresh cow's liver, suspended as usual, with flat surface exposed. Bullet velocity 1,000 feet p. s., 5 feet from muzzle. Entrance opening, through centre of liver, of the diam. of the projectile; rear opening 15 mm. long and broad. The track is slightly funnel shaped, some liver substance is scattered over the paper, and there is one fissure 1 cm. in length and 5 mm. in depth.

7. Jan. 8, 1898. Pig's kidneys, just removed from the animal, suspended in such a manner that they present their anterior surfaces. Bullet, with a velocity of 2,560 feet

p. s., at 20 feet from muzzle, entered centre of right kidney, and bore away entire medullary portion, including pelvis. The vertical diam. of opening is 5 cm , the transverse diam. 2.5 cm. long. The capsule shows numerous fissures near the exit. Kidney substance pulped for some distance from the opening. A second shot, fired at the left kidney, almost completely destroyed it.

8. Jan. 22, 1898. Kidneys from a young bullock, recently killed. The organs were suspended as usual, with anterior surfaces exposed. The bullet, with a velocity of 1,000 feet, at a distance from the muzzle of 5 feet, entered: *a*, the centre of the right kidney, causing an entrance opening of 6 mm. and an exit of 7 mm. in diam., the parenchyma in a pulped condition, completely filling the track; *b*, the centre of the left kidney, entrance 6 mm., exit 8 mm., with several small fissures in capsule. A fine wire pushed through the track produces a small quantity of pulp.

9. Jan. 22, 1898. A fresh bullock's heart, still surrounded by the lung, which is not inflated perfectly. The right ventricle faces the shot which is aimed at its centre. The bullet enters with full velocity, at 5 feet from the muzzle. The entrance opening in the wall of the right ventricle is 3.5 cm. long and 2 cm. broad, exposing the muscular substance. There is one fissure running from the lower border of the opening towards the apex, 4 cm. long and in part extending through the entire thickness of the muscular wall. The exit is an irregular large-sized hole, freely exposing the inner cavities of the organ, showing that a portion of the septum has been carried away, and a portion of the heart is in shreds. The same shot pierced the lung behind the heart, which apparently suffered from the explosive effect produced in the heart. The entrance is 4 cm. in diam., the exit 10 cm. long and 4 cm. broad. Part of the muscular substance of the heart was carried right through the lung, being found scattered over the canvas cloth hung up behind it.

10. March 12, 1898. A calf's heart, just removed and in a state of firm contraction, having evidently stopped beating in systole, suspended by a bandage wound around the origin

of the great vessels so that both the right and left ventricles were in sight. The bullet, with a velocity of 1,163 feet, fired 10 feet from the heart, passed through exposed portion of the left ventricle about 5 cm. above the apex, making a round, clean entrance, 6 mm. in diam. The exit was found over the dividing line between the right and left ventricle, included a portion of the septum, and measured 8 mm. in diam., rather oval than round; the entire track is smooth and shows not the least injury to any other portion of the heart.

Reviewing the results obtained from the above series of shots, we find, in the first place, that the shot through the brain of the young calf, when compared to injuries of other parts produced with the same velocities, is altogether unique and exceptional. Such an injury, produced in man, would have elicited not only a favorable prognosis from the beginning, but would have ended in a good recovery. Very interesting, also, are the fine shades of difference to be noticed between the injuries of the liver and those of the kidneys, as produced by the same velocities. The relatively larger amount of fluids contained in the liver over that contained in the kidney is quite sufficient to explain this difference. The high degree of explosive effect produced by the highest velocity bullets becomes less great as the velocity decreases, and ceases altogether when the velocity has reached 1,000 feet p. s. We may, therefore, conclude that the limit for the production of explosive effect on viscera by our bullet lies somewhere in the neighborhood of 1,000 feet, which velocity will probably be found to lie near a point corresponding to a distance of a thousand yards from the muzzle of a gun fired with full charges of ammunition.

B. BONES AND JOINTS.

Under this head I will describe a few shots, through each type of bone, made with different velocities. Since the material in this series was chiefly derived from a young ox and a calf, both of which had just been killed by a shot through their brains, other injuries will be mentioned incidentally.

1. *Lower jaw.* — A full-velocity bullet struck and went through both rami of the lower jaw of a young ox, 90 feet from the muzzle. The skin entrance measured 10 mm. in diameter, had serrated edges, and a narrow margin around the opening was deprived of hair. The bone entrance was round and measured 6 mm. in diam. The exit, on the right side of the animal's jaw, showed a skin wound, 1.5 cm. long and 1 cm. broad, with ragged edges. Underneath the skin is felt a swelling, caused by bone dust and semi-coagulated blood. Culling off the skin from the left side of the lower jaw, or the entrance, a longitudinal slit-like opening in the fascia is noticed and which measured 2.5 cm. in length and 1 cm. in breadth. This fascia, also, showed some bulging due to a collection of bone dust and blood between it and the bone. In the bone underneath this tumor was found a round opening, 6 mm. in diam., but widening to 10 mm. at the exit from the left side of the lower jaw; here, also, are found numerous fine spicules, pointing in the direction in which the shot went, and still adhering to the periosteum. On the right side the bullet had simply carried away a small square piece of bone near the ankle, leaving an irregular hole in the bone and causing a tumor-like protrusion made up of bone dust and blood.

2. *Lower jaw.* — A bullet of 1,500 feet velocity, aimed at the lower jaw of a cow. The head was so disposed that the bullet had to pass through both sides of the bone at 5 feet from the muzzle. The bullet entered at a point midway between the ankle and the teeth of left side, causing an entrance 6 mm. in diam., with an exit of 16 mm. in diam.; passing on through the right side of the jaw, it gave rise to an entrance of 8 mm. in diam., and an exit of 32 mm. in diam. The track was decidedly funnel-shaped and the marrow was exposed. This shot shows the influence of gradually increasing deformity of bullet on size of wound.

3. *Ilium.* — A 6-mm. bullet, with a velocity of 750 feet p. s., entered the flat surface of the ilium, 5 feet from the

muzzle, causing an entrance of 6 mm. in diam. and an exit of 8 mm. in diam. The injury is a clean perforation without any fissuring or splintering.

4. *Shoulder plate.* — A bullet with a velocity of 750 feet p. s. entered supra-spinous portion at a distance of 5 feet from the muzzle, giving rise to an entrance of 6 mm. and an exit of 7 mm. in diam. without splintering or fissuring.

It will be noticed, then, that even in flat bones in which clean perforative injuries with hard-jacketed bullets are the rule, with even the highest velocities, with our bullet these are obtained only with the lowest velocities.

5. *Neck.* — A full-velocity bullet struck the neck of a young ox, 90 feet from the muzzle, about midway between the head and shoulders. The skin entrance was a typical hole of 7.5 mm. in diam., the exit, not exactly in line with and opposite to the entrance, was an irregular opening, 22 mm. long and 15 mm. wide. The subcutaneous tissues, immediately adjacent to the exit, are distended and crowded with bone dust and blood. The margins of the wound are angular, with three fissures starting in various directions and each 1 cm. long. Small detached pieces of the mantle and of the lead from the projectile were found mixed with the sandy contents of the tumor-like protrusion underneath the skin in the immediate neighborhood of the opening. The finger, which is introduced without difficulty, touches the broken surfaces of vertebræ at the bottom of the wound. On the left side, or the side of the entrance of the bullet, dissection reveals a narrow track leading to a tumor of the size of a goose's egg, enclosed in white fibrous tissue, and through the centre of which there is an opening or passage filled with coagulated blood. Incising this tumor, we find it filled with semi-coagulated blood and in the centre of it, and passing in a longitudinal direction, a large vein is discovered which is empty, showing a lozenge-shaped opening without, however, having lost its continuity. The tumor, in other words, is what is generally known as a peri-vascular hæmatoma. Further dissection showed that the bodies of two adjacent vertebræ were broken into several pieces, and parts of these,

partially ground up into bony detritus, are lining the track beyond and leading towards the exit on the other side. The middle of the track was several times more spacious than even the exit opening in the skin; the bony contents were grayish discolored from lead, and contained also small pieces of copper from the projectile.

6. *Wrist.* — A full-velocity bullet struck the wrist of a young ox, 90 feet from the muzzle. Typical entrance. Exit, on opposite side, is 3 cm. long and 1.5 cm. wide, its edges are jagged and torn; there is a tumor-like subcutaneous swelling, packed so full of bone sand and coarse splinters that the finger cannot be introduced. Several small pieces of the projectile were found mixed up with the mass.

7. *Ankle.* — A bullet with a velocity of 750 feet p. s. entered the ankle-joint of a cow at a distance of 5 feet from the muzzle of the gun. The entrance in soft parts was smaller than the diam. of the projectile, and some bony detritus could be seen through it. At first no exit could be found, but on searching further an opening was discovered, corresponding in size to the diam. of the bullet, but at right angles to its line of entrance and in a plane with it. On the same side of this opening, on the floor of the room, was found the lead of the bullet bent so as to form a quarter circle. Opening the joint, the empty jacket was recovered, embedded in a partly broken cuboidal bone. The rear end of the lead, found on the floor, fitted well into the jacket of the projectile found in the joint.

8. *Epiphysis of femur.* — A full-velocity bullet entered the outside of the knee-joint of a young ox, at a distance from the muzzle of 90 feet. There was a typical skin entrance. The adjacent portions of both femur and tibia were completely ground up into bony detritus, filling the cavity of the joint. Two long and deep fissures pass upward in femur, the lower end of which presents three tooth-like spines 1 cm. in length. The narrow cavity is empty and glistening. The blood vessels are completely destroyed, and there is not the slightest trace to be seen of the articular surfaces. The entire joint cavity is simply packed solidly with detritus which, in

part, is protruding through on the side opposite to the entrance, looking into the body of the animal. The projectile is in pieces, and mixed with the detritus filling up the cavity of the joint.

9. *Epiphysis of tibia.* — A bullet with a velocity of 1,500 feet struck the epiphysis of the tibia of a cow at a distance from the muzzle of 5 feet. Both the entrance and the exit are smaller in diameter than the bullet. Neither opening shows the least sign of splintering. A wire passed through the track made by the bullet produced a small amount of moist bone dust, which looks reddish, and feels sandy to the touch.

10. *Metaphysis of tibia.* — A bullet of a velocity of 1,500 feet p. s. struck the tibia of a cow about 4 cm. from the head, and at a distance from the muzzle of 5 feet. The entrance was typical, and of the diameter of the projectile. From the entrance in the bone, and extending downward, may be seen a broad, flat bony lamina, 6 cm. long, 15 mm. broad, raised above the surface of the surrounding bone, immovable, and tightly adhering to it. Exit in the bone, 7 mm. long and 5 mm. broad, shows not the least splintering or fissuring. At a distance of 2 cm. from this opening, however, there commences a fissure 75 mm. long, slightly elevated, not movable, exposing the narrow cavity, and passing in the direction of the diaphysis of the bone.

11. *Metaphysis of tibia.* — A bullet of a velocity of 1,000 feet p. s. entered the lower metaphyseal portion of a tibia from a cow at a distance from the muzzle of 5 feet. The entrance opening in the bone is of the diam. of the projectile, but forms the starting-point for a fine fissure in the most superficial layer of the bone, 8 cm. long. The exit is an ovoidal opening, exposing a funnel-shaped cavity in the substance of the bone, through which the entrance opening is easily seen. A fissure 1.5 cm. in length passes from the exit in a direction towards the diaphysis of the bone.

12. *Diaphysis of tibia.* — A bullet with full velocity entered the leg of a young ox, passing through the centre of the diaphysis of the tibia, at a distance from the muzzle of

90 feet. The skin entrance is a typical hole of the diam. of the projectile. The exit is a long rent in the skin, through which splinters of bone and shreds of muscles protrude. The bone is completely broken in continuity. Several pieces of bone, 3 and 7 cm. long respectively, are easily removed through this opening, and many smaller pieces are driven into the neighboring tissues. Contents grayish discolored, and mixed with parts of the projectile.

13. *Diaphysis of tibia.* — A bullet of 1,500 feet velocity passed through the centre of the diaphysis of the tibia of a cow, at a distance of 5 feet from the muzzle of the gun. The result was a butterfly fracture (Bornhaupt), though not a typical one, being accompanied with long fissures and extensive splintering. The entrance in the bone is 1 cm. in diam., the exit 6.3 cm. The splinters remain adhering to the periosteum, exposing a portion of the marrow cavity of the size of a pigeon's egg. The cavity is lined with small pieces of lead, its contents grayish discolored.

14. *Diaphysis of tibia.* — A bullet moving with a velocity of 750 feet p. s. entered the centre of the diaphysis from a cow. The entrance in the bone is 10 mm. in diam., rather quadrangular, and from each corner of the quadrangle there starts a deep fissure; these four fissures pass upward and downward, two on each side of the cylindrical bone, and diverging as they pass, also exposing the marrow and comprising the entire thickness of the bony cortex. The upper and outer of the four fissures is 6 cm. long, the lower and outer 3 cm. long; the upper inner fissure is 5 cm. long, and the lower inner 4 cm. long. The exit presents a longitudinal opening, 14 cm. long and 3 cm. broad, exposing the marrow. Several pieces of bone hanging into the cavity by the periosteum.

From the accounts of the injuries on bones we find that the injuries produced by the highest velocities are simply terrible, and those produced by the lowest, far from benign. Although the injuries which have been described in the preceding pages as occurring under different and varying conditions of experimentation on animal structures and organs cannot be directly applied to the living human subject, they have been selected from a very large number, and will be found of material value. It is not within the scope of this paper to draw any very detailed and far-reaching conclusions as regards the treatment of the injuries as they are likely to occur in the human subject, but, whatever else may be brought to light by future experimentation on the human cadaver or by accidents occurring either during peace or on the field of battle and produced by our projectile, one thing is certain; namely, that the explosive zone has been extended and its penetrative power lessened, owing to the softness of the jacket and the consequent ease with which the bullet is deformed when striking bones or other hard substances.

It may be assumed with a fair show of reason that such injuries as will probably be produced in the human subject by our projectile will influence the methods of treatment both in the rear of the fighting-line and in the hospitals afterwards, in that they will require the treatment laid down for "near-shots" (Nahschüsse), that is to say, they must from the very beginning be treated as infected injuries. Owing to the further fact that the projectile often goes to pieces, portions of its copper jacket and of its lead lining the track, we may reasonably expect that amputations will have to be done more frequently, and that the percentage of mortality will be higher, no matter how well equipped the hospital nor how skilful and experienced the surgeon.

Boston Society of Medical Sciences, January 24, 1899.